

Smut and root rots on native rushes (Restionaceae) and sedges (Cyperaceae)

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Abstract

Native rushes (Restionaceae) and sedges (Cyperaceae) are widespread and common components of the vegetation of south-west Western Australia. In phytopathological terms many taxa within these families are susceptible to indigenous smut diseases, which affect culms and reproductive organs, yet are apparently resistant to habitat invasions by *Phytophthora* species. Smut disease has been found in a quarter of the 113 species of Restionaceae, representing 11 out of the 19 genera for the State, and in 17 species and 9 genera of Cyperaceae. For many species, smut diseases result in total loss of viable seed production. Culm smut has been recorded in only one species, and in this case infection results in retardation in growth and development of culms and reduced seed output. Conversely, introduced *Phytophthora* species have limited impact on survival and reproduction of native Restionaceae. Controlled inoculation of *P. cinnamomi* shows that disease symptoms are confined to localised regions on the roots, with a limited degree of cross infectivity between roots. Infected roots of test species produce abundant, healthy lateral roots above the lesions and symptoms in shoots are not apparent. The use of Restionaceae as barrier plantings for containing infection to sites within a habitat or protecting sites of rare taxa which are susceptible to *P. cinnamomi* is presently being investigated. An understanding of the diseases of rushes and sedges is important for the management of these plants in natural communities and in horticultural enterprises.

Introduction

Until recently, the effect of disease on Restionaceae has been limited to taxonomic description of species of smut (Ustilaginales) on host plants (McAlpine 1910) and the increase in rush and sedge abundance in wild sites affected by *Phytophthora* (Wills 1993). Many smuts have been described on the closely related Cyperaceae and the impact of *P. cinnamomi* on sedges has been studied in eastern Australia (Weste 1986; Phillips & Weste 1984; Cahill *et al.* 1989).

Southern-hemisphere rushes and sedges are widespread and common components of the flora of south-west Western Australia. They inhabit a wide range of the northern sand plains, coastal wetlands and to a lesser extent the jarrah forest. Most species are long-lived perennials, with culms initiated from an underground rhizome in late autumn to early winter. Most Restionaceae are dioecious, with a few monoecious and hermaphroditic species, while sedges are monoecious. All species of both families flower from early winter to early summer, are wind pollinated, with most species producing very few viable seeds which are short lived and germinate in response to soil disturbance (Meney & Dixon 1988, Meney *et al.* 1994). Taxa can be classified into two broad groups, seeders and resprouters, depending on their reproductive and vegetative biology, and their response to disturbances, such as fire. Their life strategies occur along a continuum from fire sensitive seeders, recruiting from seed after fire, to resprouters which regenerate

from heat resistant or deeply buried perennating buds located on the rhizome (Pate *et al.* 1990).

An understanding of the impact of *Phytophthora* and smuts on native rushes and sedges is critical, as many species are harvested extensively from natural populations for use in the floriculture industry. Many species are also important in rehabilitation of mining areas due to the sand-binding nature of their roots (Pate & Dixon 1994) and dominance in pre-mined vegetation (K Meney *pers. comm.*).

Impact of smut on native rushes and sedges

McAlpine (1910) described smuts on nine sedge species and two rush species from Eastern Australia. He wrote of the Western Australian smuts, "Only those species are known which attack cultivated crops and those occurring on the native flora are yet to be discovered". In the last seven years, 43 rush and sedge species in 20 genera have been recorded as smut hosts in Western Australia (Table 1). These smuts are as widespread as their hosts and represent the most debilitating pathogens of rushes and sedges. Thus, smut impacts are likely to play a significant role in rehabilitation and conservation of these families in the future.

Taxonomy

The taxonomy of smuts is based on spore morphology, mode of spore germination and specialisation at host genus level. There are about 43 new species among these smuts and their taxonomy is currently under investigation. With the exception of one smut, all sporulate in inflorescences and have affinities to *Tolyposporium*. One species, *T. restionum*, has recently been described on a native rush *Alexgeorgea*

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nitens (Nees) L Johnson & B Briggs (Websdane *et al.* 1994). The exception to the inflorescence smuts is the culm smut *Ustilago lyginiae* (Websdane *et al.* 1993) on *Lyginia barbata* (Labill) R Br. This is the first record of a culm smut on Restionaceae.

Table 1
Recorded hosts of smuts within Restionaceae and Cyperaceae in Western Australia

| Restionaceae | | Cyperaceae | |
|-----------------------------------|----------------------------|-----------------------------------|---|
| Genus | Species | Genus | Species |
| ¹ <i>Alexgeorgea</i> | <i>A. nitens</i> | ⁴ <i>Carex</i> | <i>C. fascicularis</i> |
| | <i>A. subterranea</i> | | |
| ³ <i>Anarthria</i> | <i>A. laevis</i> | ⁶ <i>Caustis</i> | <i>C. petandra</i> |
| | | ³ <i>Cyathochaeta</i> | <i>C. avenacea</i> <i>C. clandestina</i> |
| ³ <i>Desmocladius</i> | <i>D. biformis</i> | ³ <i>Evandra</i> | <i>E. aristata</i> |
| | <i>D. elongatus</i> | | |
| | <i>D. flexuosus</i> | | |
| ³ <i>Harperia</i> | <i>H. confertospicatus</i> | ⁵ <i>Isolepsis</i> | <i>Isolepsis sp.</i> |
| ³ <i>Hypolaena</i> | <i>H. fastigiata</i> | ³ <i>Lepidosperma</i> | <i>L. angustatum</i> |
| | <i>H. macrotepala</i> | | <i>L. effusum</i> |
| ³ <i>Lepidobolus</i> | <i>L. chaetocephalus</i> | | <i>L. gladiatum</i> |
| | <i>L. deserti</i> | | <i>L. gracile</i> |
| | <i>L. preissianus</i> | <i>L. Longitudinale</i> | |
| ³ <i>Leptocarpus</i> | <i>L. aristatus</i> | ³ <i>Mesomalaena</i> | <i>M. gracileps</i> |
| | <i>L. ceramophilus</i> | | <i>M. pseudostygia</i> |
| | <i>L. elegans</i> | | <i>M. stygia</i> |
| | <i>L. scariosis</i> | ³ <i>Shoenus</i> | <i>S. laevigatus</i> <i>Schoenus sp.</i> |
| ³ <i>Lepyrodia</i> | <i>L. macra</i> | ³ <i>Tricostularia</i> | <i>T. neesii</i> |
| ^{2,3} <i>Lyginia</i> | <i>L. barbata</i> | | |
| ³ <i>Pseudoxocarya</i> | <i>P. magna</i> | | |
| | <i>R. chaunocoleus</i> | | |
| ³ <i>Restio</i> | <i>R. isomorphus</i> | | |
| | <i>R. leptocarpoides</i> | | |
| | <i>R. microcodon</i> | | |
| | <i>R. sinuosa</i> | | |
| | <i>R. sphacelata</i> | | |
| | <i>R. stenandra</i> | | |
| | | | |
| Totals | 26 | | 17 |

Identity of smuts associated with host taxa.

¹*Tolyposporium alexgeorgii*.

²*Ustilago lyginiae* (culm smut).

³Tentatively identified as *Tolyposporium* species (inflorescence smuts).

⁴Tentatively identified as *Farysia* species.

⁵Tentatively identified as an *Anthracoidea* species by R Shivas

⁶Unidentified

Symptoms

The symptoms of inflorescence smuts are not always obvious, as the spore mass or sorus is generally enclosed in the inflorescence. In Restionaceae, smut infections manifest as massive sporulation by the fungus in the ovaries (Fig 1-1) and anther sacs of inflorescences. Infection results in partial to total loss of seed productive capacity. In the monoecious Cyperaceae, the sorus surrounds developing anthers and stamens rendering them sterile.

Transvestism is an interesting abnormality observed in several dioecious rush species affected by smuts. For example, when smutted the normally pendulous male inflorescences of *Restio microcodon* L Johnson & B Briggs take on the appearance of healthy, erect female inflorescences (Fig 1-2). Thus, in transvestite-susceptible species, partial smutting results in male plants appearing to be hermaphroditic. Indeed, transvestism in smutted male inflorescences of *A. nitens* led to its misidentification by Nees (1846). The nor-

mally tufted inflorescences (Fig 1-3) become swollen when smutted (Fig 1-4) and, according to Nees, resembled inflorescences of female *Restio* species. Nees called the host species *R. nitens* and mistook the smut for a rust which he named *Uredo restionum*. Johnson & Briggs (1896) resolved this misidentification and clarified the taxonomic identity of the host. The identity of the pathogen has also been clarified recently as *T. restionum* (Websdane *et al.* 1994).

In certain other host species examined, the only evidence of smut infection was a slight swelling of the host inflorescence and in many sedges smutted spikelets cannot be distinguished from those which are healthy.

The culm smut recorded on *Lyginia barbata* is easily recognised as a raised, brown, crust-like structure, or peridium, derived from host epidermal cells, which encloses the powdery spore mass (Fig 1-6). These spores have high viability, germinate readily and survive for at least one year and possibly longer. Spores of inflorescence smuts on the other hand appear to have either a long period of dormancy or a short period of viability and spores of most of these smuts have not been successfully germinated. The development of the culm smut sorus occurs during culm growth and well before inflorescence initiation. The sorus prevents further development of culms eventually causing dieback of culm apices. Thus all infected culms are sterile (Fig 1-5; Websdane *et al.* 1993).

Disease impact

Smuts often fully replace the reproductive structures of host plants and render the plants sterile. In many seeder species, smut infection causes total loss of reproductive capacity in infected plants. Field observations on the resprouter species *A. nitens* indicate that smut infection is systemic via the ramifying rhizome system. This was shown by tracking rhizomes from smutted parent plants to underground buds and enclosing developing buds in spore-proof glassine bags. At inflorescence maturity all new plantlets originating from smut infected parent plants were also infected, indicating systemacy (K Websdane, unpublished data).

Disease incidence

Smuts have been found on hosts from isolated, undisturbed habitats. For example, a population of *Lepidobolus deserti* Gilg was found to have less than 1% smutting at the Queen Victoria Springs on the edge of the Great Victorian Desert. It appears however that disturbance exacerbates the disease incidence as 20 to 50% smutting has been recorded in populations experiencing frequent fires, mining activities or road works (K Websdane, unpublished data).

Implications of smut disease for conservation and restoration

Smut infection is likely to be a problem in post-mining situations where successful restoration of species of rushes and sedges is dependent on creating self-sustaining populations of plants producing seed and healthy seedlings. For example, smutted plants of *Lepidobolus chaetocephalus* Nees, a seeder species, experience up to 100% loss of seed production in sites adjacent to mining areas in northern

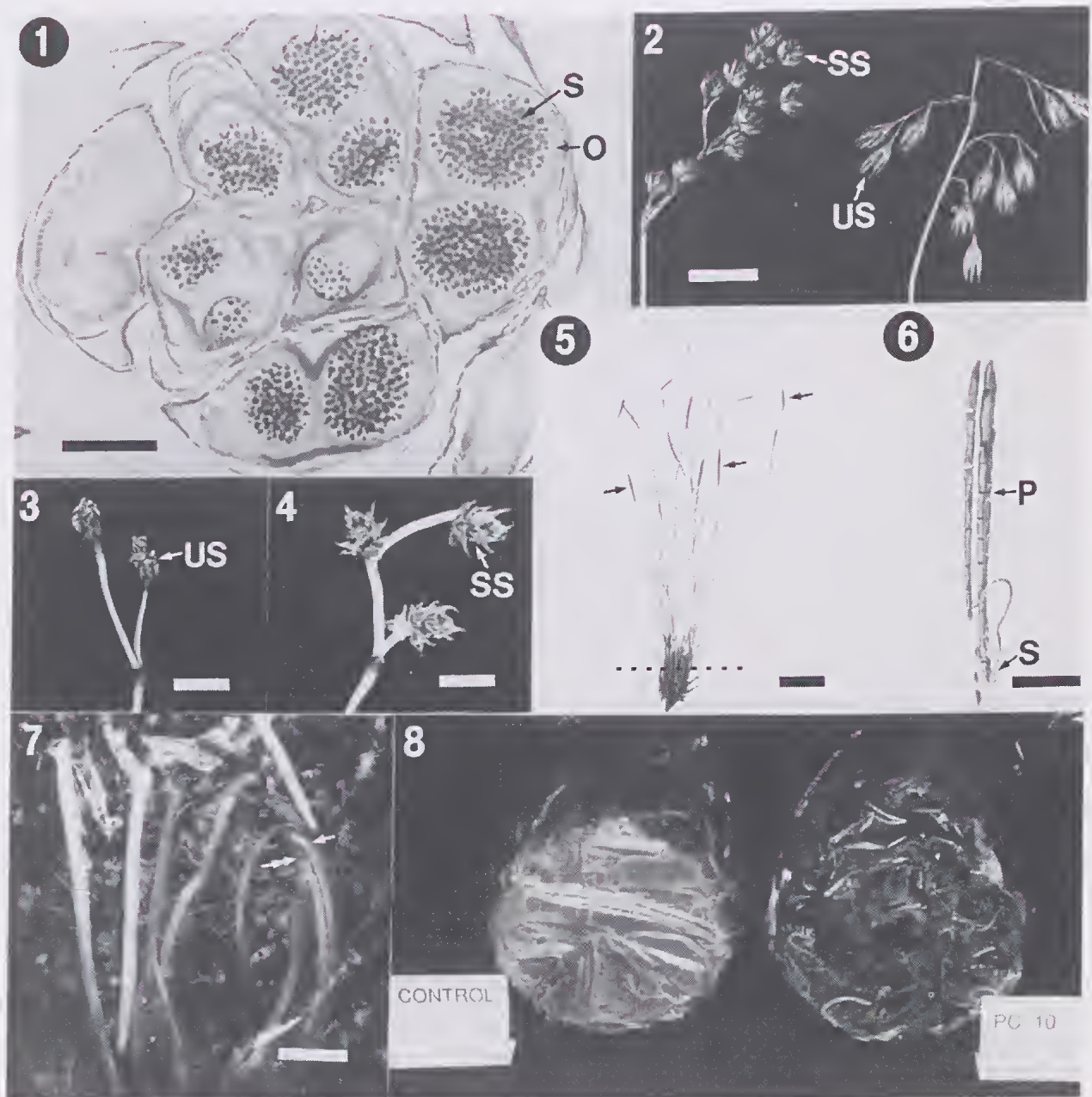


Figure 1. 1. Cross-section of female *R. microcodon* spikelet showing the production of smut sori in ovaries, preventing seed production. S=sorus O=ovary wall (bar=1mm). 2. Smutted spikelets (SS; left) and uninfected spikelets (US; right) of a male *R. microcodon* plant. Smutted male spikelets appear identical to healthy female spikelets (bar=1cm). 3. Uninfected spikelets (US) of a male *A. nitens* plant (bar=0.5cm). 4. Smutted spikelets (SS) of a male *A. nitens* plant thought by Nees (1846) to resemble female spikelets of *Restio* species (bar=0.5cm). 5. Whole plant of *L. barbata* infected by *U. lyginiae* (culm smut) showing sori (arrows) (bar=5cm). 6. Close-up of culm smut sori along a culm of *L. barbata*. P=peridium. S=scale leaf. (bar=1cm). 7. Roots of *Loxocarya magna* root rot symptoms. Healthy lateral roots (arrow) are initiated above water soaked lesions (double arrow) (bar=2cm). 8. The difference in root mass, at the base of the pot, between control and inoculated plants of *Loxocarya magna*.

Kwongan regions. This has serious implications for the survival of this species in rehabilitation programs. This host relies on current season seed production for seedling recruitment after fire, rather than soil seed banks (Meney 1993). Thus, a high incidence of smut infection and fire can result in death of parent plants and dramatically reduced seedling recruitment. These factors, in addition to high levels of seedling mortality recorded for this species (Meney *et al.* 1994), may result in localised extinction of this species (K Websdane, unpublished data).

Of the 17 rush and sedge species harvested from the wild for the cut-flower industry, half have been recorded as hosts for smuts. In a number of these species infection of inflorescences is diagnosed only after careful examination. This means that smutted inflorescences could unknowingly be harvested along with those which are healthy. The disease is therefore likely to have an impact on the sustainability of bush harvesting and on product quality particularly for export markets. It is critical for pickers to be aware of the disease in order to recognise and avoid smutted plants and populations and prevent the export of diseased material around the world.

Impact of *Phytophthora cinnamomi* on native rushes and sedges

Since the invasion of *P. cinnamomi* into the sclerophyll forests of Australia there has been a marked reduction in the diversity of understorey species present in infested sites (Weste 1986, Wills 1993). Members of the Epacridaceae and Proteaceae which are highly susceptible to the pathogen have been replaced by monocotyledons, especially members of the Restionaceae and Cyperaceae. Within the Stirling Range National Park a greater number of Restionaceae species were recorded in old-infested sites than healthy sites and their percentage cover increased significantly from four percent in healthy sites to ten percent in old-infested sites, with a similar increase in the abundance and frequency of Cyperaceae in long term, diseased sites (Wills 1993). The dominance of these species in diseased areas has been attributed to their field resistance to *Phytophthora* root rots.

Previous research showed *P. cinnamomi* to infect the roots of three species of sedges from the Brisbane Ranges in Victoria (Phillips & Weste 1984, Cahill *et al.* 1989), however only field observations have been made on the field resistant nature of the Restionaceae. The resistance of two species of Restionaceae to increasing levels of *P. cinnamomi* inoculum was studied under glasshouse conditions. Clonally propagated plants of *Loxocarya magna* Meney & Dixon (ined) and *Restio amblycoleus* F Muell were inoculated with *P. cinnamomi*. Examination of the roots eight weeks later showed the development of water-soaked lesions immediately behind the root tip but new lateral roots formed above these lesions and limited cross infection was apparent (Fig 1-7; Sieler *et al.* 1993). Inoculated plants of *L. magna* produced a greater number of thick, depth-seeking roots and fewer bifurcated laterals than control plants (Fig 1-8). There were no symptoms in the above-ground portion of the plants except for some yellowing of juvenile leaves and culm tip die-back in some treatments. Production of new reproductive culms was high for all inoculated plants, with a greater number of new culms being produced at high levels of inoculum. The ability of these plants to produce new roots and reproductive culms once infected has important implications for the rehabilitation of affected sites and the management and recovery of rare species of rushes and sedges.

At least 11 species of rare and endangered or priority rushes and sedges are located in areas infested with *P. cinnamomi*. The potential benefits of field resistance in rushes and sedges is considerable including reinforcement and reintroduction into disease affected areas. In addition, species such as *R. ustulatus* (F Muell ex Ewart & Sharman) L which is both a priority species and recorded as being harvested, may be used in the reclamation of sites or high risk horticultural sites as an alternative to bush picking.

The use of rushes and sedges to act as biological barriers to reduce the impact and rate of spread of *P. cinnamomi* is currently being investigated. Phillips & Weste (1989) showed zoospores to be produced from infected roots of the sedge *Gahnia radula* but the potential of infected roots to act as a future source of inoculum is not known. In a study of the barrier potential of Restionaceae to *P. cinnamomi*, adult plants of *R. amblycoleus* were placed into the middle of pots divided into three portions with Mira cloth (Calbiochem. Corp, La Jolla, USA). *Banksia* seedlings were planted on either side of

the rushes and one set of plants inoculated with *P. cinnamomi*. In comparison to control pots, banksias in pots containing rushes showed a mark reduction in disease presence and delayed movement of inoculum. Passage of *P. cinnamomi* through the soil occupied by roots of a rush has been slow, and studies are continuing to determine the effectiveness of the Restionaceae as a biological barrier to the movement of the pathogen through soil.

Conclusions

Although there is a great diversity of flora in Western Australia, phytopathological studies have concentrated on those components which are most visibly affected by pathogens. In contrast to the timber and highly floriferous species, only limited work on disease impact and interactions has been conducted on the Cyperaceae and Restionaceae. Their importance in floriculture and rehabilitation of mine sites, *Phytophthora* affected areas or high risk horticultural sites indicates a more economic role for these families in the future and the need for on going research.

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